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Airsickness Prevention in Helicopter Passengers: A Comparison of Four Countermeasures

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13. ABSTRACT *(Maximum 200 words)*

Despite many existing treatments, airsickness remains an issue of concern in today's military. This study used a double-blind, between groups, placebo-controlled design to compare the effectiveness of four airsickness countermeasures: three pharmacological and one non-pharmacological. All flights were conducted in an actual UH-60 Black Hawk helicopter. Sixty-four, male, non-aviator subjects (ages 18 to 34) were recruited from Fort Benning, Georgia. Sixteen subjects were randomly assigned to each of four groups: 1) promethazine (25 mg)-caffeine (200 mg), 2) meclizine (25 mg), 3) scopolamine (1.5 mg), and 4) ReliefBand. Each individual participated twice, once with the treatment and once with placebo. The findings indicate that only the combination of promethazine-caffeine produced a statistically significant reduction in nausea and motion sickness severity, and improvement in reaction time when compared to its placebo control and the other countermeasures. Data from this study indicated that of the countermeasures tested, promethazine-caffeine is the most effective at reducing airsickness with the least adverse side effects.

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Introduction and military significance

Airsickness has been a serious aeromedical concern since World War II. During that time, it was reported that at least 10% of flight students became sick during their first few flights. Rates of airsickness as high as 50% were reported in other aircrew members. Additionally, unfavorable flight conditions produced airsickness in as many as 70% of airborne troops. A great number of the airborne Soldiers were virtually disabled upon reaching their target areas (Armstrong, 1961).

Despite many existing treatments, airsickness is still an issue of concern in today's military. The symptoms exhibited by individual Soldiers can range from mild discomfort to vomiting, drowsiness, lethargy, and apathy. Thus, the impact on an operational unit can also vary from degraded performance efficiency to severe manpower losses. Certain in-flight conditions such as turbulence, heat, or degraded visual cues due to deteriorating weather or night flight can leave aircrew members in situations which may predispose to airsickness. Additionally, Soldiers being transported to a mission under these conditions can be equally, if not more, affected due to reduced experience with in-flight conditions. The physiological and psychological performance problems associated with such situations can compromise mission effectiveness.

Soldiers must be ready to execute missions at any given time during or post flight, so minimizing the symptoms of airsickness such as nausea, fatigue, and apathy is critical. In the operational environment, airsickness should be treated with the most effective medications which yield the fewest negative side effects. Many of the currently available pharmaceutical countermeasures must be given in high doses to be effective. Unfortunately, high doses of antiemetics can produce sedation, which is unacceptable in terms of mission effectiveness. Several nontraditional motion sickness and nausea remedies are now gaining acceptance in the medical and lay communities, particularly acupressure and acustimulation. Such remedies should be examined for their effectiveness in military contexts such as rotary-wing flight. Thus, this experiment examined airsickness symptoms, the efficacy of some potential treatments, and the effects of the treatments on basic motor and cognitive performance. This study mimicked the operational transport of Soldier teams in the crew cabin of a UH-60 Black Hawk flying a profile utilizing many of the flight maneuvers included in a troop insertion.

Background

Dizziness, nausea, vomiting, drowsiness, pallor, sweating, and overall malaise that are triggered by travel in a boat, car, train, or plane all fall into the category of motion sickness (Lawther and Griffin, 1988). Motion sickness has been well known for thousands of years. Ancient seafaring nations were very familiar with this malady. This problem has become increasingly prevalent in the modern world with the development of many forms of vehicular travel. The syndrome appears to arise from a disturbance in the vestibular apparatus, organs used to maintain balance and sense orientation and movement. The most widely accepted theory concerning the cause of motion sickness focuses on sensory mismatch between the visual and vestibular systems (Eyeson-Annan et al., 1996). For example, passengers on cruise ships are far more likely to get seasick when below deck because their vestibular apparatus detects motion while their visual system does not (Gordon et al., 1994). Standard advice for such seasickness is

to go up on deck where vestibular and visual inputs agree. Similarly, studies have shown that children are less likely to become car sick when elevated in a seat that provides a good outside view (Fischer, 1998).

Airsickness, however, is more problematic. An outside view doesn't necessarily help in aviation, because flight constantly presents sensory conflicts. During a coordinated turn, for example, our eyes show a tilted horizon while our vestibular sense says we're perfectly upright. Uncoordinated maneuvers and turbulence provide even more complex conflicts. In a cloud, many vestibular sensations may be received while the visual system reports a featureless, horizonless void. Passengers are far more prone to motion sickness than are the pilots (DeHart and Davis, 2002). This is not surprising considering that motion sickness is often triggered by discrepancies between anticipated orientation and actual orientation. For pilots at the aircraft controls, knowledge of upcoming flight movements seems to offer some protection against acquiring the symptoms of airsickness as compared to passengers and crewmembers (DeHart and Davis, 2002). Additionally, with repeated exposure, pilots will desensitize to the effects of sensory mismatch (Gillingham and Previc, 1996). This desensitization often does not occur in passengers. In fact, the Navy has reported that 13.5% of all flights will lead to airsickness in non-pilot crew members (Guedry, 1991).

Treatment of motion sickness

Nausea and vomiting are the most common complaints of motion sickness and are mediated by central neurotransmitters. In response to visual and vestibular input, increased levels of dopamine stimulate the medulla oblongata's chemoreceptor trigger zone, which in turn stimulates the vomiting center within the reticular formation of the brain stem. The vomiting center also is directly stimulated by motion and by high levels of acetylcholine. Therefore, most drugs that are used to prevent or ameliorate motion sickness symptoms target these neurotransmitters. While the precise action of these medications in preventing motion sickness is not known, most of these drugs fall into three classes: antidopaminergics, anticholinergics, and antihistamines (Facts and Comparisons, 1999; Physician's Desk Reference, 2001). Additionally, sympathomimetic agents often are added to the drug regime in order to counter the frequent side effect of somnolence.

Antidopaminergics

The most effective antidopaminergic agent currently approved for motion sickness is promethazine hydrochloride, a phenothiazine derivative with antihistamine, anticholinergic, and sedative effects (Physician's Desk Reference, 2001). It is useful for both active and prophylactic treatment of motion sickness. Promethazine has largely been used in situations of severe stimuli as both a prophylaxis and for treatment of established motion sickness (Kohl, Calkins and Mandell, 1986; Wood et al., 1990). Promethazine causes more drowsiness than many of the other standard antiemetic agents and its use is reported to result in significant decreases in performance, psychomotor function, information processing, and alertness, and thus, is often used in conjunction with a stimulant-like agent.

Anticholinergics

Currently, the most popular anticholinergic agent used for treatment of motion sickness is the centrally acting antimuscarinic scopolamine hydrobromide (Transderm-Scop) which is usually delivered via a cutaneous patch applied to the skin behind the ear. The patch delivers a continuous dose of scopolamine to the systemic circulation for up to 3 days. Scopolamine prevents motion-induced nausea by inhibiting vestibular input to the central nervous system (CNS), resulting in inhibition of the vomiting reflex (Brown and Taylor, 1996). It also may have a direct action on the vomiting center (Clissold and Heel, 1985).

Antihistamines

Numerous antihistamines are available to prevent motion sickness, although it is likely that their benefit is derived from their intrinsic anticholinergic properties, rather than their antihistamine properties (Babe and Serafin, 1996). The most popular of these agents is meclizine hydrochloride, a histamine-receptor blocker that presumably prevents motion sickness by blocking muscarinic receptors in the CNS. Meclizine treatment has long been considered an effective regimen and is available in a tablet that can be swallowed, chewed or allowed to dissolve in the mouth. Its ease of use is a main advantage but drowsiness is a potential side effect (Physician's Desk Reference, 2001).

Non-pharmacological remedies

Alternative medicine remedies are becoming increasingly popular and many have been recommended for treatment of motion sickness (Blumenthal, Goldberg, Brinkmann, 2000; Cummings and Ullman, 1997; Dobie and May, 1994; Ernst and Pittler, 2000). Acupressure has generated a great deal of interest as a non-pharmacological means of preventing motion sickness because it has been shown to be effective in the suppression of nausea and vomiting (Bertolucci and DiDario, 1995; Bruce, Golding, Hockenhull, Pethybridge, 1990). To control nausea and vomiting, pressure is applied to the pericardium 6 (P6) acupuncture point (Neiguan acupoint) on the pericardial meridian, located about 3 cm from the distal palmar crease between the palmaris longus and flexor carpi radialis tendons. One study involving a popular acupressure wristband that applies pressure to this area found that continuous vigorous stimulation of the P6 point was required to achieve a significant benefit (Hu et al., 1995). One such version of the wristband provides constant electrical stimulation to the P6 point.

Somnolence Countermeasures

Sympathomimetic drugs counteract the drowsiness produced by some pharmacological motion sickness treatments. Dextroamphetamine sulfate and various formulations of ephedrine are the most common and have been used to avoid sedation in situations where alertness is required (Physician's Desk Reference, 2001). Unfortunately, both types of drugs have become stigmatized in today's society. Amphetamines are known to be extremely addictive and possess high abuse potential (Hoffman and Lefkowitz, 1990). Even at recommended therapeutic doses, dextroamphetamine has been known to produce psychotic episodes, over-stimulation, restlessness, dizziness, insomnia, euphoria, tremors, and headaches.

While the addictive properties of ephedrine are yet unclear, the Food and Drug Administration has issued warnings about ephedrine use, sales are banned or restricted in at least 20 states, and the American Academy of Neurology released a press statement adding that consumption of ephedrine products may cause serious neurologic side effects. A review by the Texas Department of Health identified 500 adverse events, including eight deaths, associated with dietary supplements containing ephedrine, pseudoephedrine, norephedrine, or N-methylephedrine (Nightingale, 1996; American Academy of Neurology Press Release, 1996; MMWR, 1996).

Caffeine is considered a non-addictive stimulant (American Psychiatric Association, 1994) with many of the same behaviorally activating properties as the amphetamines and ephedrine compounds. Caffeine stimulates the central nervous system first at the higher levels, the cortex and medulla; and finally at the spinal cord with higher doses. Mild cortical stimulation appears to be beneficial resulting in clearer thinking and less fatigue (Lieberman et al., 1987). Caffeine is also known to improve physiological performance and mood in fatigued individuals (Lieberman et al., 1987; McLellan, et al., 2005) and has been shown to improve attention in tasks such as simulated night driving (Leinart and Huber, 1966).

Study objectives

1. Using a military helicopter, determine the effectiveness of selected airsickness remedies (promethazine-caffeine, meclizine, scopolamine, and a non-pharmacological alternative - acustimulation relief band) for preventing airsickness symptoms and ameliorating performance declines.

2. Make recommendations to military commanders concerning the potential of each treatment for use in operational military conditions.

Methods

General

This study was conducted by personnel of the U.S. Army Aeromedical Research Laboratory (USAARL) and the Fort Benning Martin Army Community Hospital using the USAARL's JUH-60A Black Hawk helicopter at Lawson Army Airfield, Fort Benning, Georgia. As it is common for helicopter movements of infantry troops to occur during night conditions when outside visual stimuli are obscured or totally absent, the windows were covered with UH-60 blackout curtains. The flight profile included a variety of maneuvers similar to those experienced during air assault operations that exposed the passengers to rapidly changing vestibular input. A double-blind, between groups, placebo control design was used to compare the effectiveness of four airsickness countermeasures (three pharmacological and one non-pharmacological) to placebo control and to each other. Because the extent of airsickness symptomatology is extremely variable among individuals, each person received one treatment and one placebo control flight. Additionally, as most people become asymptomatic after repeated exposures and recency of flight is an issue (DeHart, 1996), helicopter flight experience was limited to less than 10 hours

and flights were scheduled seven days apart. Participants completed pre- and post-flight test batteries designed to examine symptomatology and cognitive and basic motor performance.

The USAARL JUH-60A Black Hawk helicopter (Figure 1) was used as the test platform. The aircraft accommodated eight volunteers per flight.

Figure 1. The USAARL JUH-60A Black Hawk helicopter.

Study population and description

Sixty-four, male, non-aviator subjects (ages 18 to 34) were recruited to participate in this study. Sixteen subjects were randomly assigned to each of four groups: 1) promethazine (25 mg) + caffeine (200 mg), 2) meclizine (25 mg), 3) scopolamine (1.5 mg), and 4) ReliefBand®. Each individual participated twice, once with the treatment and once with no active treatment (placebo). Three different types of treatments were used (drugs taken orally, drugs in a transdermal patch, and a wristband). To keep participants unaware of their treatment group or order, several placebo measures were used. For oral drugs, a placebo capsule indistinguishable from the drug capsule was used. All participants had a large band-aid placed on the back of the neck, behind the ear, concealing the presence or absence of the medicated patch. The wristbands were worn backwards, with the stimulus-producing side on the dorsum of the wrist (away from the median nerve) as a placebo control (Figure 2). An elastic wrist "sweatband" was worn over the ReliefBand® to conceal the device from investigators and other participants. In this study, the ReliefBand® was turned on and volunteers were allowed to self-adjust stimulation levels (1 to 5). Volunteers kept the band on until post-testing was completed. Each participant experienced one flight with one active measure and two placebo measures and one flight with three placebo measures.

Figure 2. The wristband (ReliefBand®) being placed in the placebo position.

Since the aircraft only reasonably accommodated eight subjects at a time, each flight included two subjects from each treatment group, one having been administered the treatment and the other under placebo. Thus each flight had four individuals using a treatment (one of each treatment) and four individuals posing as the placebo controls for each treatment. Table 1 below lists the treatment and control procedures used with each group.

Table 1.
Treatment and control procedures.

Treatment Group	Number of Subjects	Experimental Treatments	Control Treatments
Promethazine (25 mg) + caffeine (200 mg)	16	Promethazine Placebo patch Wristband backwards	Placebo capsule Placebo patch Wristband backwards
Meclizine (25 mg)	16	Meclizine Placebo patch Wristband backwards	Placebo capsule Placebo patch Wristband backwards
Scopolamine patch (1.5 mg)	16	Placebo capsule Scopolamine patch Wristband backwards	Placebo capsule Placebo patch Wristband backwards
ReliefBand® non-pharmacological	16	Placebo capsule Placebo patch ReliefBand®	Placebo capsule Placebo patch Wristband backwards

Inclusion and exclusion criteria

Only male Soldiers (ages 18 to 34) with limited (<10 hrs) rotary-wing flight experience were used in this study. As the degree and frequency of airsickness is known to decrease with repeated exposure, conclusions based on the effectiveness of the countermeasures could be compromised by using subjects with widely varying amounts of flight experience. Based on the target population (infantry, special operations troops), female Soldiers were not used as volunteers as they are currently excluded from the infantry population. Caffeine use in excess of 400 mg per day on average, use of any medication, prescribed or otherwise, deemed unable to be discontinued safely for the duration of the protocol by the physician investigator, and use of any medication which could have interacted with any of the agents used in this study disqualified the volunteer.

Procedure

Testing procedures

Volunteers reported to the Lawson Army Airfield Base Operations, Fort Benning, GA, at 0700 on their scheduled test day. Scopolamine patches or placebo patches were applied. After breakfast and following placement of patches, pre-flight baseline measures on the postural balance test, psychomotor vigilance task (PVT), progressive cognitive capacity checker (PC3), and the motion sickness questionnaire (MSQ) were obtained. All participants received the same lunch meal to include a non-caffeinated beverage. A single capsule of promethazine-caffeine, meclizine, or placebo was given and subjects were privately fitted with the ReliefBand® and given either correct or placebo instructions on usage.

Volunteers were loaded into the aircraft using an assigned seating arrangement in order to avoid the introduction of a potentially confounding variable, seat position. All subjects sat in forward facing seats. The flights begin 2.5 hrs after the end of lunch. A flight medic from the 498th Medical Company (Air Ambulance) accompanied the volunteers on the flight and a study physician remained in constant contact on the ground.

Subjects were able to withdraw from the study at any time, even during the flight. Two participants requested that the flight be terminated early, however, their request came during the final pattern of the flight profile (Appendix B), so, in effect, they experienced the entire flight profile. In the aircraft, each participant requesting a flight termination was instructed to raise his hand. The flight medic, conducting continuous observation of the participants, immediately notified the pilots of a volunteer's desire to terminate the flight.

The flight profile (Appendix B) was divided into two 15-minute segments. Between these segments, the helicopter passed over the start point on the runway. If a participant felt too sick to continue, the helicopter crew was prepared to land momentarily, allowing the subject to disembark and be received by research staff. This never occurred as explained above.

Post-flight measures on all tests were collected immediately following flight termination. Volunteers spent approximately 5 minutes at each of 4 test stations. The tests were administered

in a round robin fashion. For example subjects 1 & 2 started at test station 1, following test completion they moved to station 2, then moved to 3, and finally ended with station 4.

Apparatus

PVT

A portable simple reaction time test, the PVT is known to be sensitive to the effects of fatigue and sleepiness (Dinges et al., 1997) (Figure 3). It displays a 3-mm light in a window for up to 1.5 seconds during which time the subject responds by pressing a microswitch which records reaction time to the stimulus. The interstimulus interval varies randomly from 1 to 10 seconds.

Figure 3. Subjects performing the PVT.

ReliefBand®

Weighing 1.2 ounces, the ReliefBand® is a wrist worn device which contains electronics plus a pair of coin-size lithium batteries (Figure 2). The underside of the device has a pair of gold-plated electrodes that contact the skin. It is worn like a sports watch on the underside of the wrist. The face of the device has a dial that permits it to be turned on and off and adjusted to any of five stimulation levels. The wearer turns the device on and adjusts the dial until a mild tingling sensation is felt. This device has received FDA clearance for treatment of nausea and

vomiting due to pregnancy, chemotherapy, motion sickness, and as an adjunct to antiemetics for postoperative nausea.

Tests

MSQ

Subjective sickness symptoms were measured using a laptop version of the MSQ (Kellogg, Kennedy and Graybiel, 1965) (Figure 4). The MSQ is a self-report form consisting of 28 items that are rated by the participant in terms of severity on a 4-point scale or with yes-no answers (Appendix A). Responses from the MSQ were automatically scored and presented on the computer screen for the physician investigator to examine. This questionnaire took approximately 5 minutes to administer.

Figure 4. Subjects taking the MSQ.

Postural balance assessment

Subjects completed a 5-minute postural equilibrium test according to the protocol specified by Gower and Fowkles (1989). There are three parts to this test. The first is referred to as "walk on floor with eyes closed" (WOFEC) and requires that the subject take 12 heel-to-toe steps with his eyes closed and arms folded across his chest. The subject is scored (0-12) based on how many steps he is able to make without sidestepping or losing his balance. Three trials of this test were completed following each flight, and the scores from all three were averaged. The second is the "standing on preferred leg with eyes closed" (SOPLEC) test which requires the subject to stand on his preferred leg for 30 seconds with his eyes closed and arms folded across his chest. The subject is scored on the number of seconds he is able to remain upright (to within 5 degrees) without losing his balance. Three trials of this test were completed following each flight, and the scores were averaged together. The third test is the "standing on non-preferred leg with eyes closed" (SONLEC) test which is the same as SOPLEC except that the subject stands on the opposite leg.

PVT

Changes in simple reaction time were assessed using the PVT.

Progressive Cognitive Capacity Checker (PC3)

The PC3 tested the participants' cognitive performance. This computerized test presents a number string and two comparison number strings beneath it. Individuals must identify which of the two strings is different from the top one and respond with a mouse press within 1.5 seconds. The test produces increasingly difficult levels and yields a chance corrected score and the total test time. This task took approximately 5 minutes.

Flight profile

The flight profile induced motion sickness by varying the movement of the aircraft and eliminating the outside visuals for the passengers (by covering the windows with blackout curtains). The flight profile included straight and level flight, hovers, turns, and ascents and descents at varying rates and speeds. The flight lasted approximately 30 minutes. A detailed flight profile is included in Appendix B. The profile was practiced numerous times prior to the study. To minimize variation, all flights were performed by the same research aviator at the aircraft controls. A 3-dimensional representation of the flight profile is depicted in Figure 5.

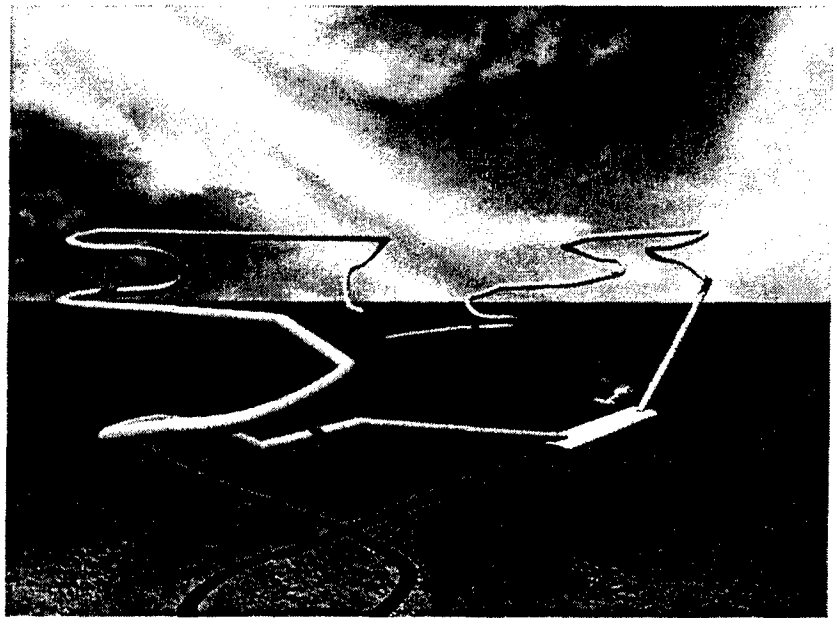

Figure 5. Flight profile.

Results

All statistical analyses were conducted using SPSS® 12.0 with statistical significance set at an alpha level of .05 for all statistical tests. Treatment group (promethazine, meclizine, scopolamine, and ReliefBand®) was the between-groups variable and experimental session

(treatment vs. placebo) was the within-subjects variable. Dependent variables from all performance tests were calculated as change scores: preflight scores minus post-flight scores. Analyses found no statistically significant differences between the four treatment groups, however, within-subjects differences were observed.

MSQ

The 28 responses on this questionnaire (Appendix A) were automatically scored by computer. The variables used from this test include scores for nausea, oculomotor disturbance, disorientation, and a score for total motion sickness symptom severity. Nausea scores are derived from the self-assessments of general discomfort, increased salivation, sweating, nausea, difficulty concentrating, stomach awareness, and confusion. Oculomotor disturbance scores are derived from self-assessments of general discomfort, fatigue, headache, eye strain, difficulty focusing and concentrating, and blurred vision. Disorientation scores combine reports of difficultly focusing, nausea, fullness of the head, blurred vision, dizziness with eyes open and/or closed, and vertigo. The total symptom severity score is the aggregate of all of the symptoms.

The data from this questionnaire were first checked for violations of assumptions of the General Linear Model. Because the distribution was not normal, the nonparametric Wilcoxon Signed Ranks Test for two related samples was used to analyze the data.

The tests revealed that the promethazine-caffeine combination was the only treatment to produce a statistically significant reduction of symptoms in any of the MSQ variables as compared to its placebo treatment. The results indicated a statistically significant reduction in nausea ($p = .010$) and in total symptom severity ($p = .033$)(Figures 6 and 7).

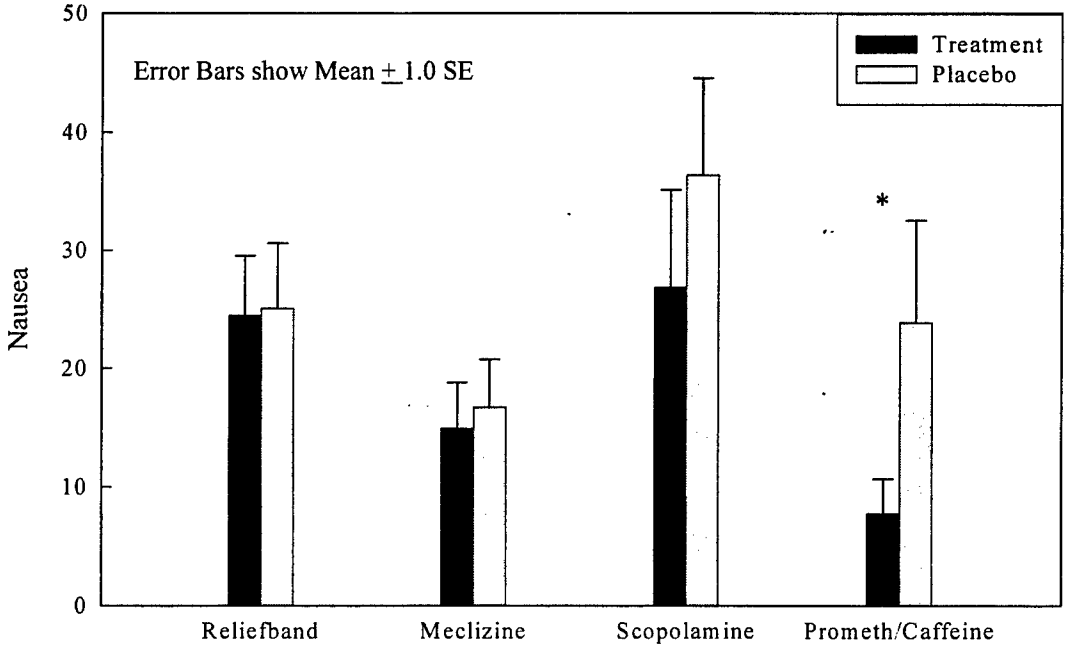

Figure 6. Nausea scores. (* indicates statistically significant difference)

Postural stability assessment

Because the distribution was normal, the data from each variable were analyzed using paired samples t-tests. The two-tailed t-tests revealed that none of the motion sickness treatments showed any statistically significant difference in any measures of the participants' postural stability when compared to its placebo.

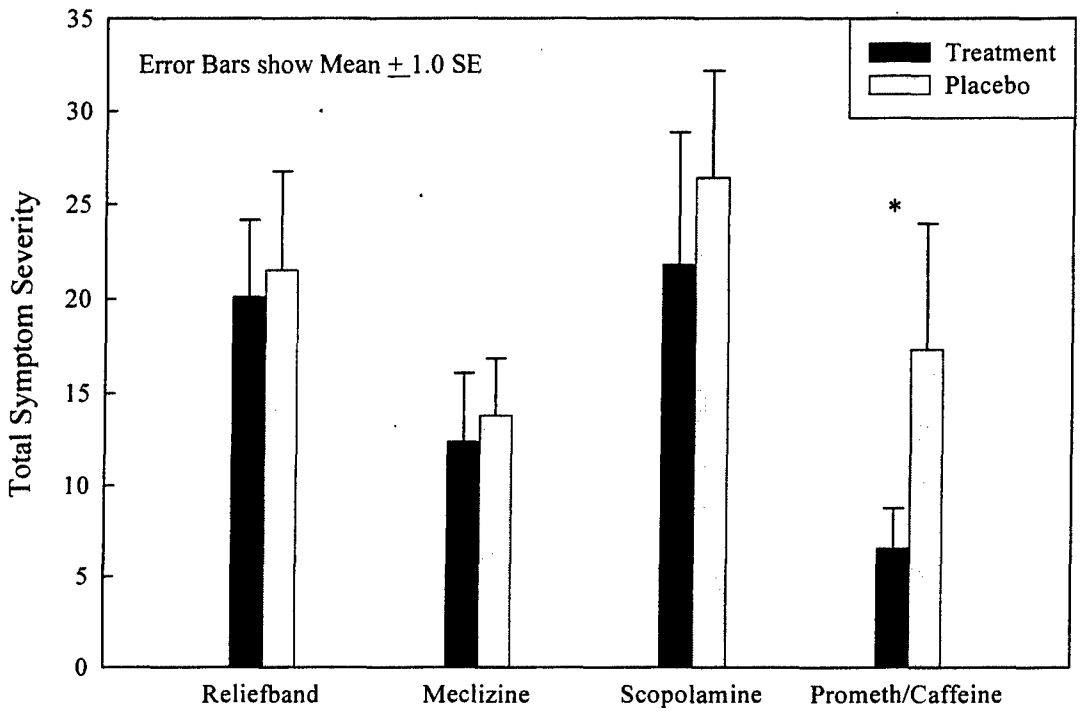

Figure 7. Total symptom severity. (* indicates statistically significant difference)

PC3

As with the previous tests in which change scores were used for the analysis, the change scores derived from subtracting post-flight PC3 chance-corrected scores from preflight chance-corrected scores are compared in this analysis. Once again, the Wilcoxon Signed Ranks Test was used due to a lack of distribution normality. No treatment demonstrated a statistically significant improvement in cognitive performance over its placebo control.

PVT

The reaction time was recorded for each PVT stimulus and was analyzed in two ways: the mean of the reaction times and the number of reaction times greater than 500 milliseconds (lapses).

The Wilcoxon Signed Ranks Test was used to analyze the PVT data because of the non-normal distribution. Two measures achieved statistical significance (Figures 8 and 9). One

measure revealed an increase in the number of reaction times greater than 500 milliseconds (lapses) by those wearing a ReliefBand® in the active condition over its placebo control (p = .014). Although the meclizine bars in Figure 8 appear to be significantly different, note that statistical significance here is based on a nonparametric ranks test rather than a parametric test. Figure 9 shows that promethazine-caffeine produced a significant improvement in mean reaction time over its placebo (p = .030).

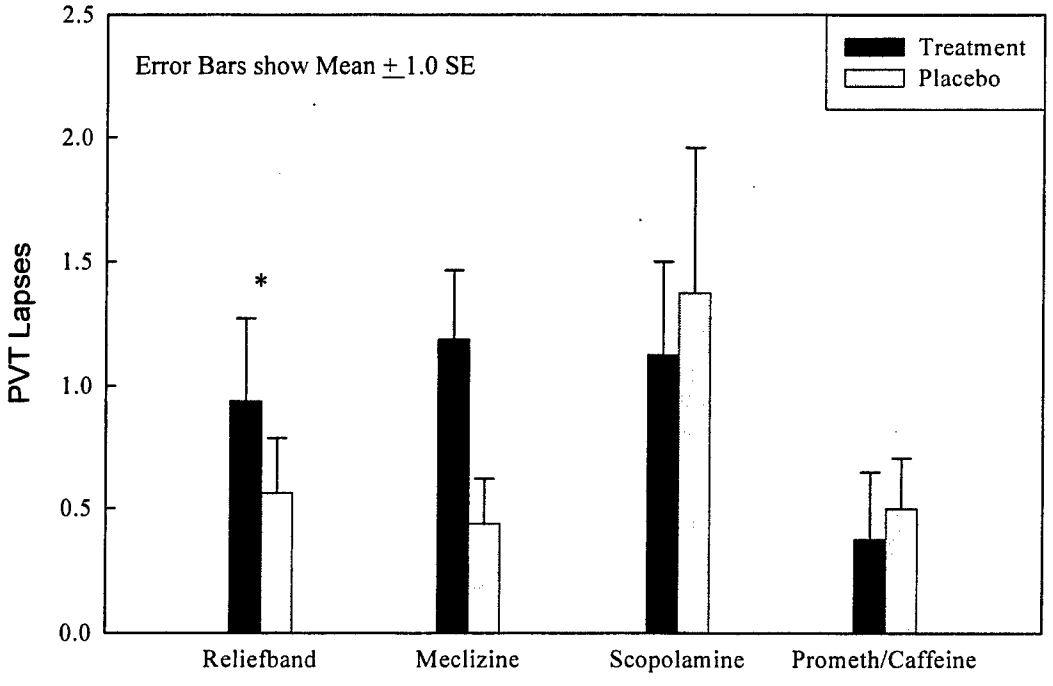

Figure 8. PVT lapses. (* indicates statistically significant difference)

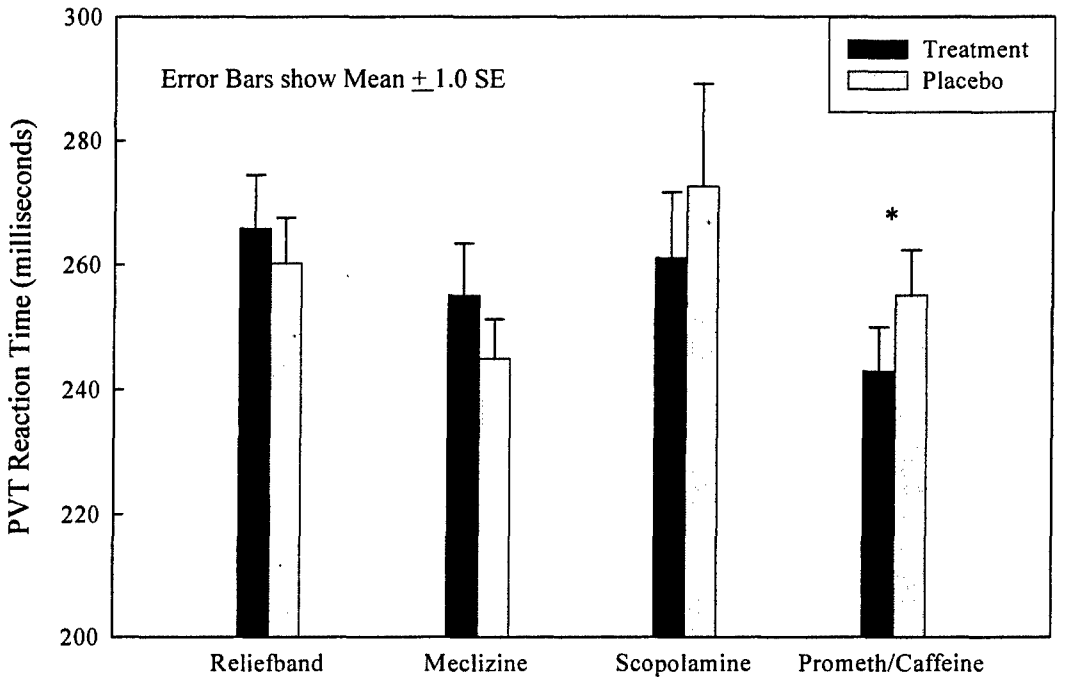

Figure 9. PVT reaction time. (* indicates statistically significant difference)

Discussion

The results of this study indicate that the promethazine-caffeine combination produced significant reductions in self-reported nausea, total motion sickness severity, and improved reaction times when compared to placebo. None of the other countermeasures tested showed any beneficial effects on airsickness symptoms.

Although no between-groups comparisons achieved statistical significance, the consistency of promethazine-caffeine to produce beneficial results over the other countermeasures warrants mention. Interestingly, there were seven episodes of airsickness so severe that vomiting occurred during the flight. Of those, two subjects were on placebo, two were wearing active ReliefBands®, two had been administered active scopolamine patches, and one had been administered the meclizine dose. No one in the promethazine-caffeine group experienced vomiting.

One can reasonably infer that the promethazine-caffeine countermeasure was the reason for the improved mean reaction time when compared to its placebo control. However, the reason for the increased number of reaction times greater than 500 milliseconds by active ReliefBand® users was initially puzzling. After conferring with the medical personnel involved in this study and reviewing the data collection procedures, it was noted that 15 of the 16 active ReliefBand® users were right-handed and used this hand to perform the PVT task. All members of this test group wore the ReliefBand® on their right wrists and thus, experienced thirty-plus minutes of acustimulation to the Neiguan acupoint (pericardium 6 or P6) of their right hand. The acupoint

P6 is located on the inside of the wrist (approximately 3 cm above the wrist on the volar surface of the forearm) and is thought in traditional Chinese medicine to relieve nausea and vomiting (Kouzi, 2003). Although the mechanism of [acustimulation] at the P6 point is undetermined, effects may be secondary to stimulation of the median nerve (Rosen et al., 2003). It is possible that the prolonged stimulation of this nerve produced neuromuscular fatigue causing slower response times of the thumb flexors (hypothenar muscle group). This hypothesis was discussed with additional subject matter experts (Campbell, 2006; Taarea, 2006) who agreed with the plausibility of this explanation.

Motion Sickness and Performance

In his 2005 study, *Introduction to and Review of Simulator Sickness Research*, Johnson, citing Reason and Brand (1975) and Kennedy and Frank (1985), reports that motion sickness does not harm performance. Johnson contends that motivation is the reason that performance is not harmed and that motion sickness "does not impair one's capability to perform; it impairs one's proclivity to perform." He suggests that if an individual can be induced to perform, he or she will perform at an acceptable level. How a task is characterized as performed at an acceptable level in the context of task complexity is not addressed by Johnson. Johnson's assertions may be true when the tasks are simple as in running or firing a weapon when chased by enemy troops. However, based on empirical observations during this study, some participants were so debilitated that even simple tasks such as running would not likely have been possible. DeHart and Davis (2002) write that recent studies of the incidence of airsickness in U.S. and British military flight training found that 15% to 18% of student pilots experience motion sickness severe enough to interfere with control of the aircraft. In light of this, it can be argued that performance on tasks requiring higher order cognitive function or precision execution could be seriously compromised in personnel suffering from motion sickness.

Flight profile

It is apparent that the flight profile (Figure 5 and Appendix B) employed to produce airsickness was effective and thus, may be considered a useful profile for subsequent airsickness studies. A full range of symptoms (from asymptomatic to nausea to active vomiting) were produced during each flight. Future studies employing this profile could include the collection of objective measures of aircraft control and subject acceleration exposure.

Order effects

The research design used in this study controlled for order effects in that half of each randomly assigned countermeasure group (8) experienced their first flight under placebo, while the other half experienced their first flight under treatment. For assurance, however, a multivariate analysis was conducted on the post-flight scores of the population with *order* as the factor and the results indicated that there was no evidence of order effects.

Heat effects

The data collection flights for this study were conducted in June 2005 at Lawson Army Airfield (LAAF), Fort Benning, GA. Temperatures experienced during the two weeks of the research flights ranged from 88° to 102° F. According to the U. S. Department of Commerce National Climatic Data Center (NCDC) (n.d.a.), the conditions were similar to those experienced in Iraq in June (85° to 95° F). In order to determine whether the results were affected by the ambient heat, the *heat index* was chosen as a factor for analysis. According to the NCDC (n.d.b.), the heat index (or apparent temperature) is a measure of the contribution that high temperature and high humidity (expressed either as relative humidity (RH) or dew point temperature) make in reducing the body's ability to cool itself. In other words, it is a measure of the temperature the body feels when heat and humidity are combined.

The heat index of each test day's 1.5 hour flight period (1330 – 1500 hours) was recorded. The indices were provided by the Air Force Weather Station located at LAAF. An ANOVA was performed of all performance data using heat index as a continuous variable. Results indicated that there were no statistically significant differences between the performance measures of the treatment groups for any of the test days and thus, no apparent heat-related effects.

Sympathetic vomiting

Post review of all the in-flight video tapes revealed that no subject sitting next to or even near a vomiting participant vomited during any flight (Figure 10). In addition, no participant reported, either verbally or in writing, that he vomited due to a sympathetic response. The use of colloid gel-filled disposable female urinals as odorless emesis bags may have contributed to the control of a potentially confounding factor.

Figure 10. Subject second from left vomiting into emesis bag during flight.

Conclusions

According to U. S. Army Aeromedical Policy Letter (1997), the current motion sickness treatment for aircrew members is either promethazine (25 mg) combined with ephedrine (25 mg) or L-scopolamine hydrobromide alone or in combination with dextroamphetamine. These are allowed for up to three occasions for flight candidates. However, there is no comparable guidance for non-aircrew passengers. Data from this study indicate that, of the countermeasures tested, promethazine plus caffeine is the most effective at reducing airsickness with minimal adverse side effects for helicopter passengers. The most common side effects of promethazine are sedation, sleepiness, occasional blurred vision, and dryness of mouth.

The lack of effect of previously proven motion sickness remedies is surprising. It is possible that the addition of caffeine to the scopolamine and meclizine treatments might alter the results. A recent study of motion sickness medications by Paul, MacLellan, and Gray (2005) reports that "relative to placebo, promethazine, meclizine, and promethazine plus pseudo-ephedrine impaired performance" on all four of the metrics (tasks) used in the study. They concluded that "only promethazine plus d-amphetamine was free from impact on psychomotor performance and did not increase sleepiness." It is apparent from their report and other studies that promethazine is effective as an antiemetic, but requires the counterpart of a stimulant to counteract its adverse side effect: drowsiness. This study demonstrates that caffeine can serve as the stimulant counterpart and when compared to d-amphetamine, is perhaps more appealing as it is available without a prescription, is relatively inexpensive, and has minimal potential for undesirable side effects and addiction.

Recommendations

Given the recommendations of the Motion Sickness U. S. Army Aeromedical Policy Letter (1997), the authors suggest that the use of promethazine plus caffeine is a safe and effective countermeasure that does not appear to produce notable performance decrements. The use of any motion sickness remedies with potential adverse effects on performance should be closely monitored by unit medical personnel and the chain of command. We recommend that further testing and research of other treatments (drug and non-drug) be continued in order to provide the user with the most effective airsickness countermeasures. Specifically, it would be useful to assess, using methods similar to those employed in the present study, other known motion sickness remedies in combination with caffeine, as well as novel approaches that stabilize the retinal image in various ways (Reschke, Somers, and Ford, 2006).

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Appendix A.

Motion sickness questionnaire.

For each symptom, please circle the rating that applies to you **RIGHT NOW**.

	1	2	3	4
General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Boredom	None	Slight	Moderate	Severe
Drowsiness	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eye Strain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Increased salivation	None	Slight	Moderate	Severe
Decreased salivation	None	Slight	Moderate	Severe
*Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
Mental depression	No	Yes		
"Fullness of the head"	No	Yes		
Blurred vision	No	Yes		
Dizziness with eyes open	No	Yes		
Dizziness with eyes closed	No	Yes		
Vertigo	No	Yes		
**Visual flashbacks	No	Yes		
Faintness	No	Yes		
Aware of breathing	No	Yes		
***Stomach awareness	No	Yes		
Loss of appetite	No	Yes		
Increased appetite	No	Yes		
Desire to move bowels	No	Yes		
Confusion	No	Yes		
Burping	No	Yes		
Vomiting	No	Yes		

Other: please
specify_____

_____

_____

_____

_____

* Sweating "Cold sweats" due to discomfort not due to physical exertion.
** Visual flashback – Illusion of movement or false sensation similar to aircraft dynamics when not in the simulator or aircraft.
*** Stomach Awareness – used to indicate a feeling of discomfort just short of nausea.

Appendix B.

Flight profile.

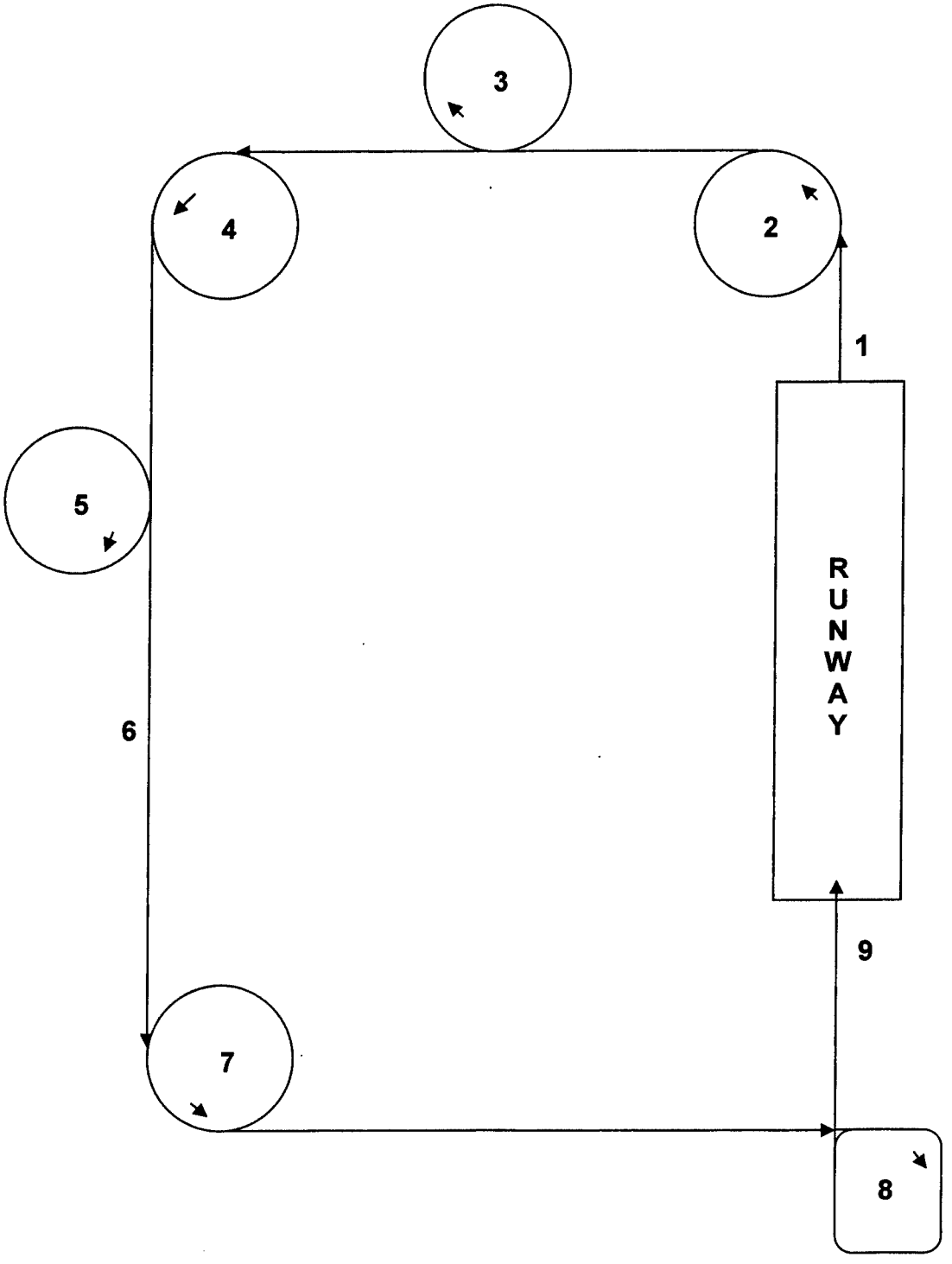
Man #	Maneuver Description	Headings	Altitude (FEET)	Airspeed
Notes:	**Ensure blackout curtains are in place.**			
	Turn SAS - OFF before takeoff.			
1	Straight Climb (Upwind) - Allow acft to PR&Y with inputs	Hdg 030 or 210	0' AGL -> 1000' MSL	0 -> 80
2	LCT (450 degrees to Crosswind) - Vary climb rate	Hdg 030 or 210 -> Hdg 300 or 120	1000' MSL -> 1500' MSL	80
3	RDT (360 degrees) - Vary descent rate	Hdg 300 or 120 -> Hdg 300 or 120	1500' MSL -> 1000' MSL	80
4	LDT (450 degrees to Downwind) - Vary descent rate	Hdg 300 or 120 -> Hdg 210 or 030	1000' MSL -> 500' MSL	80
5	RCT (360 degrees) - Vary climb rate	Hdg 210 or 030 -> Hdg 210 or 030	500' MSL -> 1500' MSL	80
6	Straight Flight (Downwind) - Allow acft to PR&Y with inputs	Hdg 030 or 210	1500' MSL	80
7	LDT (450 degrees to Base) - Vary descent rate	Hdg 210 or 030 -> Hdg 120 or 300	1500' MSL -> 1000' MSL	80
8	RDT (270 degrees to Final) - Vary descent rate	Hdg 120 or 300 -> Hdg 030 or 210	1000' MSL -> 500' MSL	80
9	Straight Descent to touchdown - Allow acft to PR&Y with inputs	Hdg 030 or 210	500' MSL -> 0' AGL	80 -> 0

Note: Repeat two times.

Flight Profile Glossary

AGL – Above ground level. Hdg – heading. LCT – Left climbing turn. LDT – Left descending turn. MSL – Mean sea level. PR&Y – Pitch, roll, and yaw. RCT – Right climbing turn. RDT – Right descending turn. SAS – Stability Augmentation System.

Airsickness Prevention Flight Profile
Two Iterations Per Group



Appendix C.

Manufacturers List

ReliefBand® Device
Abbot Laboratories
Abbott Park, Illinois
847-937-6100
http://www.abbott.com

PVT-192
Ambulatory Monitoring, Inc.
731 Saw Mill River Road
PO Box 609
Ardsley, NY 10502
800-341-0066
http://www.ambulatory-monitoring.com

TravelJohn™ Disposable Urinal
Reach Global Industries, Inc.
30 Corporate Park, Suite 107
Irvine, CA 92606
888-518-8389
http://www.traveljohn.com

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